

reinforced when the compressed gas 88 acts in the direction of closure on the one-way valve as illustrated in Fig. 5.

When a compressed gas 90 is applied in the direction of transmission on the one-way valve 38-42, said gas forces apart the two duck bill parts 86-1 and 86-2 apart, and accordingly it opens the valve. This open position of the one-way valve is shown in longitudinal section in Fig. 7 and in front view opposite the direction of transmission in Fig. 8

Fig. 9 shows the one-way valve 38/42 in sideview and rotated by 90° relative to Figs. 5 and 7.

A waiting time may be designed into all embodiments of the invention for the motion reversal positions (dead points) of the expelling elements 8-1, 8-2, to allow the pump system to come to rest before the next stroke shall be carried out.

The specification, claims and drawings describe and show preferred embodiments of the invention without thereby limiting it. The invention does also include arbitrary combinations of at least two features of the specification, the claims and the drawings.

CLAIMS

1. A pumping system for powder (54), in particular for coating powders, containing at least one powder pump (2-1, 2-2) fitted with a metering chamber (4-1, 4-2) which is bounded by a chamber housing (6-1, 6-2) and an expelling element (8-1, 8-2), said expelling element which is forward-displaceable relative to the chamber housing during a pressure stroke and backward during a suction stroke, the pump chamber comprising a powder intake duct (36-1, 36-2) associated with a powder intake valve (38-1, 38-2), further a powder outlet duct (40-1, 40-2) associated with a powder outlet valve (42-1, 42-2), and a compressed gas intake duct (44-1, 44-2) associated with a compressed gas intake valve (46-1, 46-2), the powder intake valve (38-1, 38-2) being opened to aspirate a metered quantity of powder (54) into the metering chamber (4-1, 4-2) and the powder outlet valve (42-1, 42-2) and the compressed gas intake valve (46-1, 46-2) being closed, whereby the expelling element moving in the direction of the suction stroke is

able to aspirate powder (54) through the powder intake duct (36-1, 36-2) into the metering chamber (4-1, 4-2), and the powder intake valve (38-1, 38-2) being closed in order to convey the metered quantity of powder out of the metering chamber (4-1, 4-2), and the powder outlet valve (42-1, 42-2) and the compressed gas intake duct (44-1, 44-2) are opened, as a result of which compressed gas flowing from the compressed gas intake duct (44-1, 44-2) is able to force the metered quantity of powder from the metering chamber (4-1, 4-2) into the powder outlet duct (40-1, 40-2), and a pump control unit (68) to drive the compressed gas intake valve (46-1, 46-2),

characterized in that

the pump control unit (68) comprises a time controller (74) by means of which the conveyance of powder out of the metering chamber (4-1, 4-2) is initiated as a function of the predetermined delay time elapsed since a predetermined operational point, the compressed gas being introduced at the end of the time delay into the metering chamber (4-1, 4-2) and the quantity of powder metered until the end of the time delay is forced by the compressed gas out of the metering chamber (4-1, 4-2).

2. Pump system as claimed in claim 1, characterized in that the pump control unit (68) comprises a timer and transmits each time, upon the lapse of a predetermined cycle time, control signals to a reversal device (34) to reverse the motion of the expelling element (8-1, 8-2) from suction stroke to pressure stroke and vice-versa from pressure stroke to suction stroke at the predetermined cycle time, and in that the pump control unit (68) is designed to initiate at the time controller (74) the predetermined delay time each time as a function of the time that control signal was generated which initiates the beginning of the suction stroke, the compressed gas being introduced at the end of said time delay into the metering chamber (4-1, 4-2) And the quantity of powder that was metered until the end of the delay time being forced out of the metering chamber (4-1, 4-2) by the compressed gas.

3. Pump system as claimed in either of claims 1 and 2, characterized by at least one monitoring sensor (S5, S6) detecting when the expelling element (8-1, 8-2) is at a predetermined position and generating a signal upon detecting that the expelling

element is in the predetermined position, by the pump control unit (68) being operationally connected to the minimum of one monitoring sensor, and by the pump control unit (68) being designed to automatically compare the time of the sensor signal with the time of at least one of the monitoring control signals to deduce whether the time interval between said two times deviates from a predetermined value, and by
5 generating an error signal when a predetermined deviation from the predetermined values does arise.

4. Pump system as claimed in either of claims 1 and 2, characterized in that
10 there are at least two monitoring sensors (S5, S6) which are connected to the pump control unit (68) to detect when the expelling element (8-1, 8-2) is situated in one of two different predetermined positions and to generate sensor signals when detecting the expelling element in the predetermined positions, and in that the pump control unit (68) is designed to compare the time difference between the signals from one of the monitoring
15 sensor and the signals from the other monitoring sensor on one hand and a predetermined time interval on the other hand, and to generate an error signal when the time difference deviates from the predetermined time interval by more than a predetermined value.

5. Pump system defined in claim 1, characterized in that the pump control
20 unit (68) comprises a time controller (74) to initiate powder conveyance -- as a function of the predetermined delay time elapsed after a predetermined suction stroke position of the expelling element (8-1, 8-2) -- out of the metering chamber, compressed gas being introduced at the end of the time delay into the metering chamber (4-1, 4-2) and the quantity of powder metered until the end of the delay time being forced by the
25 compressed gas out of the metering chamber (4-1, 4-2).

6. Pump system as claimed in claim 5, characterized in that the predetermined suction stroke position is a suction stroke initial position.

7. Pump system as claimed in claim 5, characterized in that the predetermined suction stroke position is situated between a suction stroke initial position and a suction stroke final position.
- 5 8. Pump system as claimed in claim 5, characterized in that the predetermined suction stroke position is situated between a suction stroke position and a suction stroke final position, nearer the former than the latter.
9. Pump system as claimed in at least one of the above claims 5 through 8, characterized in that the time controller (74) comprises at least one sensor (S1, S4; S2, 10 S3) to generate a signal when the expelling element (8-1, 8-2) is situated in a predetermined suction stroke position.
10. Pump system as claimed in one of claims 5 through 9, characterized in that it comprises a pump control unit (68) implementing the reversal of motions of the 15 expelling element (8-1, 8-2) from suction stroke to pressure stroke and vice versa as a function of signals from sensors (S1, S4) each of which generates a signal when the expelling element (8-1, 8-2) is situated along the stroke excursion at either of two predetermined motion reversal positions.
- 20 11. Pump system as claimed in at least one of the above claims, characterized in that the excursion of the expelling element (8-1, 8-2) is constantly the same size for all stroke displacements.
12. Pump system as claimed in at least one of the above claims, characterized 25 in that a second time delay takes place at least at one of the motion reversal dead points of the expelling element (8-1, 8-2) before the expelling element (8-1, 8-2) having moved in one direction is moved in the pertinent other direction.
13. Pump system as claimed in at least one of the above claims, characterized 30 in that the time delay is variably adjustable.

14. Pump system as claimed in at least one of the above claims, characterized in that the expelling element (8-1, 8-2) is a flexible membrane.

15. Pump system as claimed in at least one of the above claims, characterized in that the powder intake valve (38-1, 38-2) and the powder outlet valve (42-1, 42-2) are automatic valves which are automatically opened resp. closed by the pressure differential across their two valve sides.

16. Pump system as claimed in claim 15, characterized in that the powder intake valve (38-1, 38-2) and the powder outlet valve (42-1, 42-2) are automatic valves actuated in the manner of a check valve by differential gas pressure across their valve element (38-3, 42-3), said valve element (38-3, 42-3) being displaceable as a function of this gas pressure differential relative to a valve seat (38-4, 42-4) into its open or into its closed position and can be latched into said particular position.

17. Pump system as claimed in claim 15, characterized in that the powder intake valve (38-1, 38-2) and the powder outlet valve (42-1, 42-2) are automatic valves of the duck bill kind of which the duck bill automatically opens resp. closes on account of the pressure difference between the inside and the outside of the duck bill.

18. Pump system as claimed in at least one of the above claims, characterized in that at least two of the said powder pumps (2-1, 2-2) are used, their powder intake ducts (36-1, 36-2) being connected or connectable to a powder source and their powder outlet ducts (40-1, 40-2) being connected or connectable to a common powder feed aperture (48), and in that the two powder pumps (2-1, 2-2) are operated in opposition whereby a metered quantity of powder may be expelled in alternating manner from the metering chamber (4-1) of one powder pump (2-1) or from the metering chamber (4-2) of the other powder pump (2-2), by means of the compressed gas into the powder outlet duct (40-1, 40-2), and reversely powder may be alternatingly aspirated through the powder intake ducts (36-1, 36-2) into either of the other metering chamber (4-1, 4-2)

19. Pump system as claimed in claim 18, characterized in that the expelling element (8-1, 8-2) of the pumps are actuated by a common drive (10).

20. Powder coating apparatus
5 characterized by
a pump system as claimed in at least one of the above claims to convey coating powder.

21. Method for conveying powder (54), in particular coating powder, wherein powder (54) is aspirated by increasing the volume of a metering chamber (4-1, 4-2) from
10 a power source into this metering chamber (4-1, 4-2) and thereupon the metered quantity of powder is forced by means of compressed gas out of the metering chamber (4-1, 4-2), thereupon the volume of the metering chamber (4-1, 4-2) being decreased and next the cycle being periodically repeated,
characterized in that
15 a predetermined phase of the periodic change in volume of the metering chamber (4-1, 4-2) is detected by sensors (S1, S4; S2, S3) and in that employing a predetermined time delay after the predetermined phase has been reached, the quantity of powder metered up to that time is forced out of the metering chamber (4-1, 4-2) by means of the compressed gas.

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22. Method as claimed in claim 21, characterized in that at least one valve is used in the particular path in a powder intake duct (36-1, 36-2) into the metering chamber and in a powder outlet duct (40-1, 40-2) out of the metering chamber (4-1, 4-2), said valve automatically opening and closing in the manner of a check valve as a function of
25 the particular gas pressure difference between said at least one valve's upstream side and downstream side.

23. Method for conveying powder (50), in particular coating powder, wherein, by enlarging the volume of at least one metering chamber (4-1, 4-2), powder (54) is
30 aspirated from a powder source into the metering chamber (4-1, 4-2) and thereupon the metered quantity of powder is forced out of the metering chamber (4-1, 4-2) by

compressed air, the volume of the metering chamber (4-1, 4-2) then being decreased and next the cycle will be repeated periodically,

characterized in that

the volume changes of the minimum of one metering chamber (4-1, 4-2) are controlled
5 by a predetermined cycle time, in that following lapse of the predetermined cycle time in each case at least one control signal shall be generated, in that this minimum of one control signal reverses the direction of volume change from enlarging to decreasing resp. from decreasing to enlarging and simultaneously a predetermined time delay is initiated, and in that only when the predetermined time delay has lapsed shall the metered quantity
10 of powder be forced by the compressed gas out of the metering chamber.

24. Method as claimed in claim 23, characterized in that the volume changes of the minimum of one metering chamber (4-1, 4-2) are implemented by an expelling element (8-1, 8-2), in that the presence of the expelling element in a predetermined
15 position is determined by at least one monitoring sensor (S5, S6) and a monitoring signal is generated when the expelling element is detected in a predetermined position, and in that the time difference between the time of the control signal and the time of the minimum of one control signal is compared with a predetermined time interval which would be the time difference if the expelling element were to cover a predetermined
20 excursion within each cycle time, and in that an error signal is generated when the gap between the time difference and the predetermined time interval exceeds a predetermined value.

25. Method as claimed in claim 23, characterized in that the volume changes
25 of the minimum of one metering chamber are implemented by an expelling element (8-1, 8-2), in that monitoring signals are generated by means of at least two monitoring sensors (S5, S6) which are configured mutually apart along a path corresponding to the maximum excursion of the expelling element when it assumes a position corresponding to the sensor position, in that the time difference between the monitoring signals of one
30 monitoring sensor and the monitoring signals of the other monitoring sensor is compared with a predetermined time interval which would be the magnitude of the time difference

if the expelling element were to move along a predetermined nominal path within the cycle time, and in that an error signal shall be generated whenever the said time difference deviates by more than a predetermined value from the predetermined time interval.

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26. Method as claimed in one of claims 21 through 25, characterized in that two of the metering chambers (4-1, 4-2) undergo volume changes simultaneously but at different phases, the volume of one metering chamber being enlarged while the volume of the other metering chamber is decreased, and vice-versa.

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